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THE INSTITUTION OF PRODUCTION ENGINEERS

JOURNAL

(October, 1946, Vol. XXV, No. 10, Ed. B)

Contents:

"MODERN DRYING PRACTICE"
(with particular reference to Radiant (Infra Red) Heating)
by W. G. J. APPLETON, A.M.I.Mech.E., M.Inst.F.

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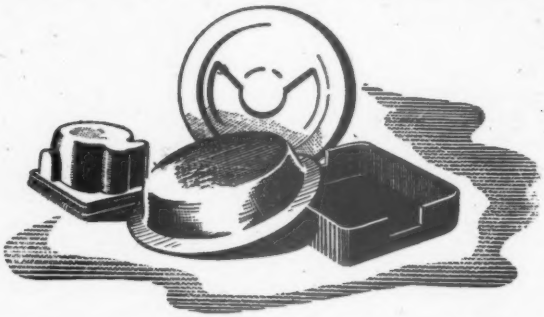

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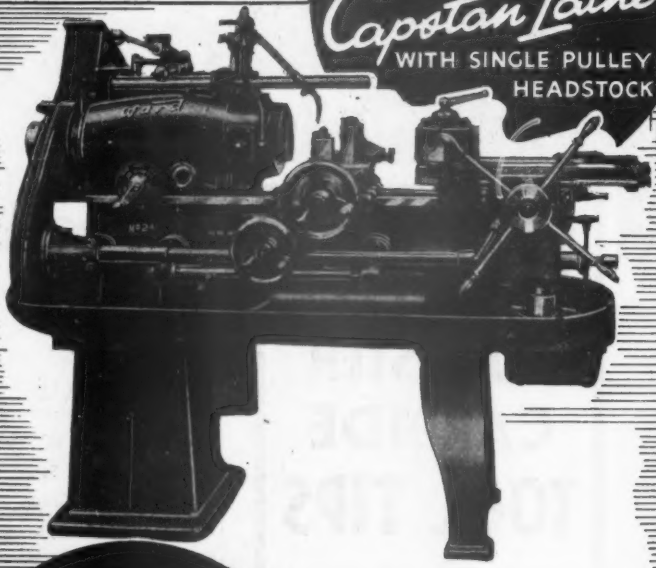

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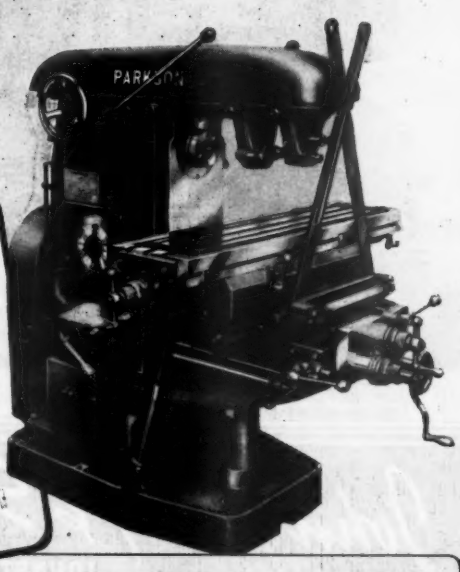

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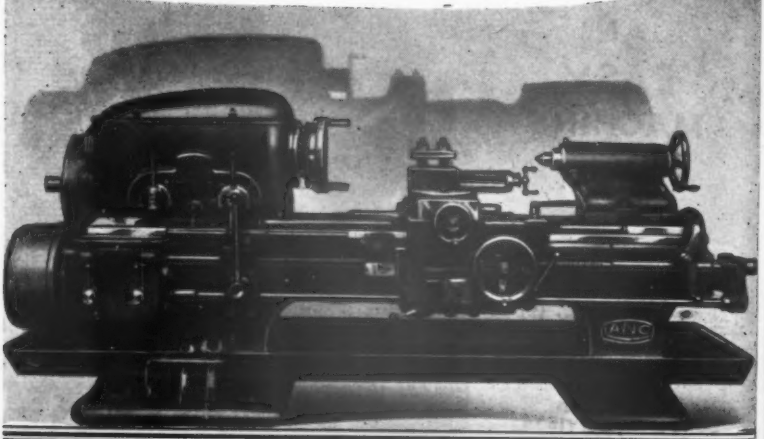

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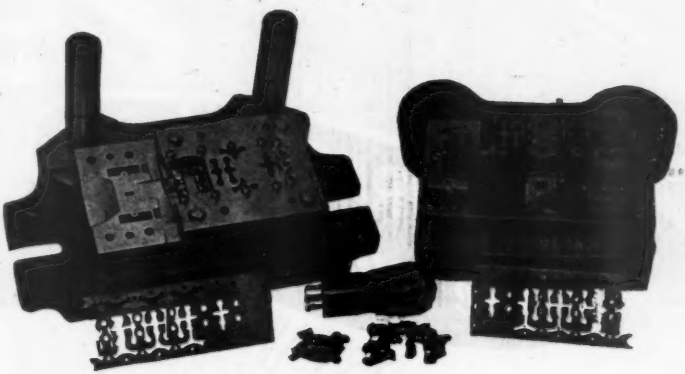

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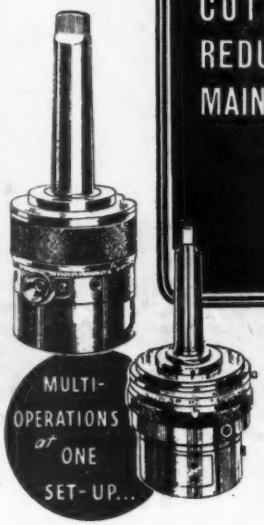

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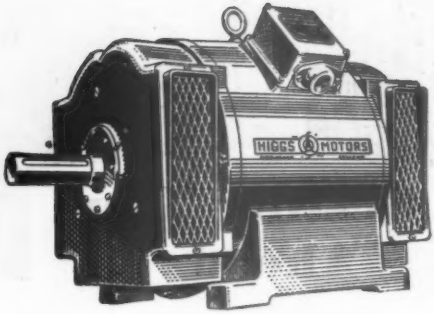

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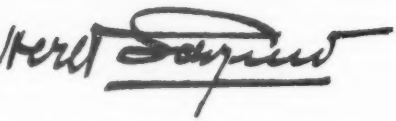
THE NEW CHAIRMAN OF COUNCIL

(1946—1947)

Dr. Herbert Schofield, the new Chairman of Council, will bring to this office a personality recognized throughout the country as outstanding in many fields. Born in 1883, he passed from an engineering apprenticeship in his father's works at Halifax to enter the Royal College of Science as a Whitworth Exhibitioner, a Carnegie Engineering Scholar, and a Royal Exhibitioner.



As the outstanding scholar of his year, he gained the first place in the first class in Mechanics and Mathematics and Physics, and was Prizeman in both Physics and Mechanics. After taking the Honours degree of B.Sc. in the University of London, he became a Research Demonstrator and obtained the Diploma of the Imperial College for original research. Later he was to receive the Ph.D.

degree of London University for work on the internal combustion engine. That his interest in research has never flagged is illustrated by the fact that it was at Loughborough College that the Institution established its Research Department in January, 1939.

The years have brought to him an ever-expanding interest in engineering in all its branches. Not only is he a member and a past member of the Councils of both the Institutions of Mechanical and Structural Engineers, an Associate member of the Institutions of Civil and Electrical Engineering, but since its inception, he has been a vital force in our own Institution and has given distinguished service both on its committees and on its Council.

His service to technical education cannot be adequately stated in a few words. History alone will do justice to the debt it owes to his foresight and his vision of possibilities all but hidden from his contemporaries. Coming to the Principalship of Loughborough College from that of Dover in 1915, he established a training centre under the Ministry of Munitions and on that slender foundation, by dogged determination and superhuman effort, careless of official and other impediments, he has built the finest engineering educational institution in the country, based on the principle of training on production.

While Loughborough grew, he gave unstintingly to wider fields of technical education. Active in the formation of the Association of Principals of Technical Institutions and their second President, he was to give a still greater service in the Association of Technical Institutions, whose Chairman he became after 21 years as Honorary Secretary.

His expert knowledge was to receive further national recognition when, in 1933, he was called to Iran to make an extensive tour of the country and report on possible developments in its system of technical education, and later when he was appointed to serve on the Consultative Committee of the Board of Education which brought out the famous Spens Report.

Alive to the social implications of industrial and professional life, he entered the Rotary movement and quickly rose to the Presidency of that body in these islands, and later became the Vice-President of the world organization.

Public recognition of his service during the first world war led to the award by His Majesty of the M.B.E., and the C.B.E. bestowed upon him in the last Honours List was a fitting appreciation of the ever-widening sphere of his efforts and interests.

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INSTITUTION NOTES

October, 1946

October Meetings

7th Yorkshire Section. A lecture will be given on "Dielectric and Induction Heating," by E. May, B.Sc., A.C.G.I., A.M.I.E.E., at the Hotel Metropole, Leeds, at 7-0 p.m.

8th Derby Sub-Section. A lecture will be given by F. G. England, Esq., Works Superintendent, Power Samas Accounting Machines, Ltd., on "Power Samas Accounting Machines," at the Art School, Green Lane, Derby, at 6.45 p.m.

9th Luton and District Section. A lecture will be given by G. H. Parlor, Esq., Int.A.M.I.P.E., on "The Rubber Bolster Press and Its Application," at the Central Library, Luton, at 7-00 p.m.

11th Manchester Section. A meeting will be held at the Mechanics Institute, Crewe, at 7-15 p.m., when H. Porter, Esq., M.I.P.E., will lead a discussion on "Machine Tool Users' Difficulties."

11th North-Eastern Section. A lecture will be given by R. W. Mann, Esq., M.I.P.E., on "Management and Production Technique Applied to the Small Engineering Industries," at the Technical College, Sunderland, at 6-30 p.m.

11th North-Eastern Graduate Section. A Film Evening will be held at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

17th Glasgow Section. A lecture will be given by L. Clayton, Esq., M.I.P.E., entitled "A Report on Management Methods," at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

18th Western Section. A lecture will be given on "Observations and Views on Heavy German Industries," by Dr. H. P. Budgen, M.Sc., M.I.C.E., M.I.Mech.E., at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

October Meetings—*Cont.*

18th Eastern Counties Section. A lecture will be given by Dr. D. F. Galloway, Wh.Sc., B.Sc. (Hons.), A.M.I.Mech.E., A.M.I.E.E., M.I.P.E., on "Surface Finish in Practice," in the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

19th Yorkshire Graduate Section. A Works Visit has been arranged to Messrs. John Lund, Ltd., Cross Hills, near Keighley, at 2-30 p.m.

22nd Wolverhampton Section. An illustrated lecture will be given by J. Loxham, Esq., M.I.Mech.E., M.I.P.E., F.R.S.A., on "The Fundamentals of Fine Measurement," at the Wisemore Schools, Walsall, at 7-00 p.m.

22nd North Eastern Section. A lecture will be given by J. Botwright Esq., on "Production Engineering in Shipyards," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

24th London Section. A lecture will be given by W. H. Tait, Esq., on "Plain Bearing Design and Application," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

November Meetings

4th Yorkshire Section. A lecture will be given by D. Clayton, Esq., D.Sc., A.M.I.Mech.E., F.Inst.Pot., on "Lubrication—Bearings and Gears," at the Great Northern Victoria Hotel, Leeds, at 7-00 p.m.

8th North-Eastern Graduate Section. A lecture will be given by J. H. Ayre, Esq., Grad.I.Mech.E., Grad.I.P.E., on "Some Principles of Moulding Tool Design for Plastics," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

9th Yorkshire Graduate Section. A lecture will be given by N. Sykes, Esq., Grad.I.Mech.E., Grad.I.E.E., Grad.I.P.E., on "Colour and its Application to Industry," at the Great Northern Hotel, Bradford, at 2-30 p.m.

13th Luton and District Section. A lecture will be given by T. F. Swallow, Esq., on "Production Management and Control," at the Central Library, Luton, at 7-00 p.m.

November Meetings—*cont.*

14th London Section. A lecture will be given by R. K. Allan, Esq., on "Some Observations of Rolling Bearing Technique," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

15th Western Section. A lecture will be given by H. Eckersley, Esq., M.I.P.E., M.I.Mech.E., on "The Manufacture and Application of Sintered Carbides," at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

18th Derby Sub-Section. A lecture will be given by H. K. Kennedy, Esq., Regional Technical Officer, Ministry of Labour and National Service, on "Training and Employment of the Disabled," at the Art School, Green Lane, Derby, at 6-45 p.m.

21st Glasgow Section. A lecture will be given by F. J. Everest, Esq., on "Gear Cutting and Finishing," at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

22nd Eastern Counties Section. A lecture will be given by B. H. Dyson, Esq., M.I.P.E., F.I.I.A., on "Motion Study", at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

23rd Yorkshire Graduate Section. A visit has been arranged to The Yorkshire Conservative Newspaper Co., Ltd., Leeds, at 2-30 p.m.

26th North Eastern Counties. A lecture will be given by C. Pearson-Smith, Esq., on "Capstan and Turret Lathe Tooling," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

Personal

Mr. Harry Moss, A.M.I.P.E., has relinquished his position as Chief Production Engineer of the Mechanical Department at Messrs. Metropolitan-Vickers Electrical Co., Ltd., Manchester, to take up an appointment as Consulting Engineer for the Midland Region of Messrs. Associated Industrial Consultants, Ltd., London.

Honours

Our sincere congratulations are extended to Mr. Savell O. Hicks, M.I.P.E., and Mr. Guy L. Norman, M.I.P.E., whose names appeared in the recent Birthday Honours List as recipients of the O.B.E.

The awards followed recognition of their services during the war years with the Ministry of Supply.

Mr. Hicks was recently released at his own request and has since been appointed to the Board of Directors of Messrs. Davidson & Co., Ltd., Belfast.

Obituary

We deeply regret to announce the deaths of Mr. Henry E. Ware, A.M.I.P.E., Machine Shop Superintendent at Messrs. Parnall Aircraft, Tolworth, and Mr. E. C. Farrell, M.I.P.E., Managing Director, Messrs. B.S.A. Tools, Ltd., Birmingham.

Books Received

"Manual of Mechanical Power Transmission." Published by Trade & Technical Press (Power Transmission), Ltd., London. Price 30s. net.

Birmingham Section Visit to Works of B.S.A. Tools, Ltd., 13th July, 1946.

The first post-war Works Visit of the Birmingham Section of the Institution of Production Engineers took place on Saturday, 13th July, when a party of members made a tour of B.S.A. Tools, Ltd., Birmingham, at the invitation of the Directors.

In addition to the Birmingham members led by their President, Mr. F. C. White, there were also present the Rt. Hon. Lord Sempill, A.F.C., M.I.P.E., Major C. B. Thorne, M.C., Director-General Secretary of the Institution, and Mr. B. Newbold, President of the Coventry Section.

The members of the party were the guests of B.S.A. Tools, Ltd., for lunch, after which Mr. F. C. White thanked the late Mr. E. C. Farrell, Managing Director, for making the visit possible, and expressed the appreciation of all members present for the splendid hospitality extended to them.

Lord Sempill congratulated the Section on choosing such a modern, up-to-date plant for their first post-war visit, and referred to the steady growth of the Institution as a healthy sign for the engineering industry in this country.

The late Mr. E. C. Farrell, Managing Director, in replying, said it was a great pleasure to welcome members of the Birmingham Section, together with so many distinguished visitors from other Sections.

His colleagues and all the Engineering Executive Staff were members of the Institution, and every encouragement was given to the younger engineers to attend the lectures. B.S.A. Tools attached the greatest importance to the splendid work being done by the Institution.

If this country was to regain its export markets and its pre-eminence in the engineering world, continued Mr. Farrell, everything possible must be done to ensure an adequate supply of competent production engineers, but in our desire to maintain our position as production engineers, we should not lose our sense of perspective or our sense of balance by overlooking the vital necessity of the training of skilled labour. He was confident that with a steady supply of young men of the right type, such as are to be found in the Institution, and provided steps were taken to assure a good supply of skilled workers, there could be no doubt as to the future prosperity of the country.

The growth and development of the Institution of Production Engineers between the wars had been one of the outstanding features of the engineering industry, but he suggested that the time had come to broaden its scope, particularly with regard to the Foundry industries. Accountants and Cost Accountants who have had practical workshop experience might also be included in its ranks.

In conclusion, Mr. Farrell congratulated the Birmingham Section on its enterprise, and also its President, Mr. Frank White, for his initiative and hard work.

Major C. B. Thorne, in thanking the late Mr. Farrell for his remarks and suggestions, emphasised the importance to modern industry of a healthy, virile body such as the Institution of Production Engineers.

Combined Intelligence Objective Sub-Committee Reports

The following titles are additional to those published in the August Journal. These reports are obtainable from His Majesty's Stationery Office, at various prices:

German Diesel Engine Industry. Final Report No. 343.

Robert Bosch & Deckel Co. (Fuel Injection Equipment). File No. XXXIII—13.

German Filtration Industry. BIOS Final Report No. 485.

Technical Survey of Electric Motor Industry in Germany. FIAT Final Report No. 498.

Investigation of German Plastics Plants, Part III (Processing of Polyvinyl Chloride). BIOS Final Report No. 445.

Combined Intelligence Objectives Sub-Committee Reports—*Cont.*

Investigation of German Plastics Plants: Part IV—Additional Information on Thermosetting Resins and Processing of Polystyrene. Final Report No. 433.

Welding of Aluminium and Aluminium Alloys, with particular reference to the Manufacture of Pressure Vessels. Final Report No. 392.

Rolled Non-Ferrous Metal Industries in Germany. Final Report No. 402.

German Fluorescent Lamp Industry and Phosphor Chemical Manufacture. Final Report No. 395.

German Electroplating Industry. Final Report No. 429.

German Commercial Air Transport Industry and Related Aeronautical Activities and Developments. File No. XXXII—24.

Report on Visit to Germany and Austria to Investigate Alloys for Use at High Temperature. Final Report No. 396.

Welding. FIAT Final Report No. 497.

Investigation of Production Control and Organization in German Factories. BIOS Final Report No. 537.

ANNUAL CONVENTION OF THE AMERICAN SOCIETY OF TOOL ENGINEERS, AT CLEVELAND, OHIO, APRIL 10th, 1946.

A signal honour was recently conferred on the Institution when it was invited to send a delegate to the first post-war Convention of the American Society of Tool Engineers.

Mr. E. W. Hancock, M.B.E., M.I.P.E., who was nominated to fill this role, flew to U.S.A. and arrived in Cleveland on 9th April. The following day he attended a meeting of the American Society of Tool Engineers Education Committee, and that evening delivered a comprehensive address to a very representative gathering of 700 guests at the Cleveland Auditorium. The subject of his address was "The History of the Institution of Production Engineers of Great Britain," during which he reviewed the circumstances leading up to the invitation, which centred around his visit to America last year, and his fortuitous meeting with Mr. Winter, Chairman of the American Society of Tool Engineers Education Committee.

Mr. E. W. Hancock, M.B.E., M.I P.E. presenting the replica of the Institution's armorial bearings to Mr. Otto Winter, Chairman of the A.S.T.E. Education Committee, who received it on behalf of the Society.

After outlining the similarity of objects and problems confronting the two organizations, the speaker proceeded to his main address, under the following headings :—

1. Why the Institution of Production Engineers was formed.
2. The chief developments of the Institution between the two wars.
3. The difficulties encountered.
4. The real test of the production engineers in Great Britain.
5. The chief activities of the Institution during the last war.
6. Its present position.
7. Its future.

The speaker then gave an outline of the inaugural meeting held twenty-five years ago, and portrayed the feelings and spirit prevailing among those present. He explained the desire of all to bridge the gap that then existed between the designer's drawing-board and the finished product by the scientific study of production problems, instead of the old rule of thumb and "leave it to the foreman" attitude.

Reviewing progress between the two wars, he emphasized the remarkable growth in the membership and activities of the Institution paying tribute to the original working members and the labours they so cheerfully undertook.

After describing the difficulties of obtaining recognition, enlivened by personal anecdote, the speaker followed the development on the educational side, which culminated in the issue of the joint Higher National Certificate in Production Engineering.

The section of the address dealing with the contribution of production engineers to the British war effort was amply supported by authentic facts and figures. These helped to define more clearly the general activities of the Institution of Production Engineers.

A concise statement of the present position, embracing membership, papers presented, research activities, and liaison with government bodies, was followed by a resume of the Institution's hopes and aspirations for the future. The importance of the Institution's general scheme for training young Production Engineers, which aimed even higher than the present standard, and which seeks to obtain nation-wide recognition of the Institution hallmark, was further emphasized.

The speaker then presented a certificate of honorary membership of the Institution of Production Engineers, in perpetuity, to the President of the American Society of Tool Engineers, together with a framed, hand-painted replica of the armorial bearings.

A graceful and eloquent tribute to those organizations and individuals, both in America and Great Britain, who had made this event possible, closed Mr. Hancock's address.

Subsequently Mr. Hancock was invited, together with the President of the Packard Motor Company, to be a Guest of Honour at a banquet held on April 11th. At this function, letters of goodwill from the President, Sir Robert McLean, and Mr. A. C. B. Owen, of Messrs. Rubery Owen, were presented to Mr. C. V. Briner, President of the American Society of Tool Engineers.

MODERN DRYING PRACTICE

with particular reference to Radiant (Infra Red) Heating

by W. G. J. APPLETON, A.M.I.Mech.E., M.Inst.F.

Presented to E. Counties Section, March 15th, 1946

The object of this paper is an endeavour to explain simply the theory of Infra Red or Radiant Heating and at the same time to compare this form of heat application with the more established systems which have for very many years been in use in industry.

The amount of publicity which, in the last few years, has been accorded to the so-called "new" form of drying bearing the magic name, "Infra Red," must have seemed the answer to all problems connected with drying in process work, and there is hardly any industry which does not at some stage in its production employ drying apparatus of some kind.

History of Radiant Heat.

It may be permitted at this point to touch briefly on the history of Radiant Heat.

The first reference on record to the association with light of radiant heat was made by Sir William Herschel, the famous astronomer, who during the course of his investigations found, that when using coloured glasses on the eye-pieces of his telescopes certain colours reduced the light but still transmitted heat and vice versa.

On further investigation he discovered that the red end of the spectrum could be extended beyond visible light and yet cause a temperature rise.

It is well known that since that time the electro-magnetic spectrum has been extended to cover ultra violet, X-rays, gamma rays (radium emission) and radiation associated with cosmic rays, whilst at the red end of the spectrum, we have infra red, and the radio frequency, ultra short waves, etc.

The first patent to be issued for the use of radiant heat for paint drying was taken out by F. J. Groven of the Ford Motor Co., who explains in his patent application that car bodies had hitherto been finished with an air drying colour varnish, the durability of which left much to be desired. This form of finish was superseded to some extent by the use of enamel but principally by lacquer, both of which were superior to colour varnish, enamel being superior also to lacquer. Enamel, however, required stoving at temperatures up to 300° F., which involved the finishing of sub-assemblies before final complete assembly. Although great care was taken during final assembly in order to prevent damage it was inevitable that a small

percentage were scratched, involving stripping down, refinishing and re-assembly. This proved so expensive in practice that lacquer finishes were in the main in use, even though this form of finish involved a final hand-polishing operation.

Groven's patent was concerned with a method of repairing blemishes to enamelled parts without stripping from the complete assembly. He used identical materials for his repair as those originally used, and applied the same number of coats. In place of the prolonged stoving given to the original finish, he proposed to use a comparatively short exposure to radiation from carbon filament lamps in gold-plated reflectors. It was found with this method that even when a door panel had to be refinished it was unnecessary to remove the glass, though the window required to be wound up.

Groven finds that a similar result can be obtained with a tungsten filament lamp, but not with a heated iron wire as a source of radiation. He covers in his patent application the use of radiation mainly confined to the range of wavelengths 0.6μ to 1.6μ.

It was a short step from the first use of radiant heat in repairing blemishes, to its use in the initial enamel coatings. Undercoats were the first production successes, since it was found that the temperature difference in the tunnel in use was too great to give first-class results with finish coats. The first units were made to follow the profile of the car body and were arranged to drop over the body and to travel with it on the conveyor line.

Finishing coats on steering wheels were then dried in a tunnel, their shape lending itself ideally to the form of tunnel with which we are now familiar.

It was some time, however, after the initial installations at the Ford Plant before the new method attained any degree of popularity, and in this country it needed the incentive of war to cause the first installations to be set down.

It was immediately apparent that the new method had much to commend it to industry, and it was also appreciated by some of the lamp companies that here was a potential large field for the sale of their products.

The gas industry, not to be outdone by their friendly enemy, immediately set themselves to the task of producing an equivalent apparatus and the gas-fired radiant tunnel was evolved.

Theory of Radiation.

It would be well if we now considered for a few moments the theory of radiation.

It is not the purpose of this paper to approach the subject from the purely scientific angle and in any case the author does not consider himself qualified to present to you such a subject. It is, however, necessary to have some idea of the fundamentals.

Three forms of heat application are available, i.e., heating by conduction, heating by convection, and heating by radiation.

For the moment we are concerned only with the third form, i.e., Radiation.

Firstly, there is nothing new in radiant heat or infra red except, possibly, the name.

All life on this planet is sustained by solar radiation, and if this failed then all life as we know it would fail also.

Many industrial processes have and are carried out entirely by the application of radiant heat, as for instance the muffle furnace in common use for all heat treatment operations, and the baker's oven. In primitive times cooking was carried out by lighting a fire in a chamber, heating the chamber to a high temperature, withdrawing the fire, and inserting the food which was then cooked by radiation.

The grill in the restaurant, or on the domestic cooker are further examples of heat treatment by "infra red" or radiation.

For low temperature application we have available two distinct forms of equipment, one employing lamps or a bright emitter as the heat source, as is instanced by the electric tunnel, and the black body radiator, instanced by the gas-fired unit.

Bright emitters can be said to obey the inverse square law, where the intensity of radiation from a point source varies as the square of distance from the radiation. This law does not, however, within limits, appear to hold in the case of the black body radiator.

It can be proved by experiment that the time to heat an object exposed to a black body radiator does not vary appreciably irrespective of the distance from the radiating source. Interesting theories have been built up to account for this phenomenon, but so far these theories are theories only and have no scientific basis.

The law commonly used when referring to radiant heat is known as the Stefan-Boltsman law, which states that when a body of area A square feet and having an emissivity E is at T_1 abs. and its solid surroundings are at T_2 abs. then the heat radiated Q is given by:

$$Q = 17{\cdot}3 \times 10^{-10} \times EA.\ (T_1^4 - T_2^4) \text{ or}$$

$$Q = 0{\cdot}173\ EA \left[\frac{(T_1)^4}{100} - \frac{(T_2)^4}{100} \right] \text{ B.T.U.'s per hour.}$$

In addition, for true consideration of this very complicated subject, two other laws should be borne in mind, namely, Kirchoff's radiation law, which states that a body at a certain temperature will radiate in proportion to its ability to absorb, and Lamberts' Law which states that the radiation from a surface in a direction at an angle with the surface varies as the cosine of the angle between the direction of radiation and the normal to the surface.

The radiation in the given direction is $q=q_n \cos \phi$, where q_n is the radiation normal to the surface.

The author offers the foregoing very brief reference with much deference, and suggests that for those interested reference be made for fuller details to Silman and Nelson's "Application of Radiant Heat to Metal Finishing," Chapter II, and to "The Efficient Use of Fuel," page 139 *et seq.* (5)

It will be appreciated no doubt that the subject in the theoretical form is a most complicated one, and in point of fact, much research remains to be done before a full knowledge of the subject is available.

In passing it may be mentioned that further complication in the study is met with due to selective absorption and radiation on which subject much work has, and is, being done, notably at Leeds University.

So much for theory and now to practice.

The Electric Radiant Unit.

Since the electric industry was first in the practical field, we should first consider the electric Radiant Unit (Fig. 1).

This normally consists of specially designed lamp bulbs which are rated at 250 watts. The lamps usually employ a tungsten filament, though, as has previously been stated, the early American tunnels

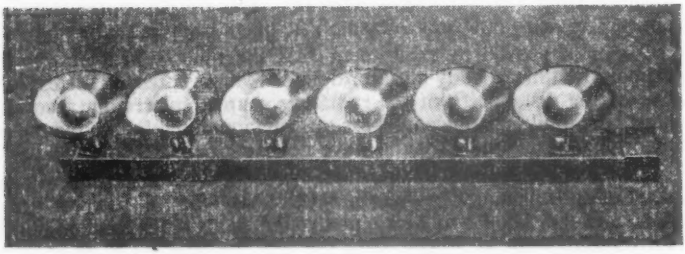


Fig. 1

used carbon filament units. The lamps are rated for 230/250 volts (wired in series to run at 110/115 volts). This has the double advantage of increasing the life of the lamp and at the same time reducing the glare factor, which on a large installation can be a matter of concern.

Various forms of lamp have been evolved in the U.S.A., including built-in reflectors incorporating screens designed to give selective radiation and also to reduce glare. The U.S.A. have also produced lamps with ratings as high as 1,000 watts.

Two types of reflector are in general use in this country, a unit parabolic type and trough type.

The advantage claimed for the trough type is that its use permits of closer pitching of the lamps with consequent higher energy densities.

Whichever type of reflector is used, the reflecting surface is generally either gold or rhodium plated.

Initially the radiating efficiency of a gold-plated reflector is higher than a rhodium one, but a gold-plated reflector very rapidly tarnishes and progressively deteriorates with each cleaning operation since gold is relatively soft, whilst rhodium is hard.

In the author's opinion, the best material for reflectors is anodised aluminium, which has a reflectivity only slightly less than gold, is virtually scratch proof and which does not tarnish. The relatively small use of aluminium for reflectors so far is due to the rigid control which was until recently placed on this material, but which has now been relaxed so that we may find an increasing use of anodised aluminium reflectors in the very near future.

With either type of reflector there is a minimum efficient operating distance for the work to give full efficiency, for reasons which will be apparent to all, since to ensure equal radiation it is essential that the reflected rays are given a chance to "settle down". The distance recommended with the majority of the conventional forms of reflectors is usually between 12"-15", though it should be stressed that the correct setting of the work should be the subject of experiment in each plant, and for each type of part.

Using the 250 watt lamp energy densities of the order of 3-6 watts per square inch 1 (1 watt per square inch=490 B.T.U.'s per square foot per hour), are commonly used. This is commonly referred to as the "flux density" of the radiator. Incidentally, since reference will be made when describing the gas-fired radiant unit of source, temperature in a tungsten lamp is of the order of 2,500° K.

In the early electric plants installed in this country, the lamps were arranged on a skeleton framework designed to follow as closely as possible the profile of the work to be dried. In order to provide for various shaped parts a "meccano" type framework was adopted so that the shape of the tunnel could be changed as required. No attempt was made in these early plants to isolate the tunnel from the shop, but due to difficulties which soon became apparent under operating conditions, and which will be referred to later, the more recent installations have tended to approach conventional stove design.

The First Gas-Fired Radiant Tunnel.

The gas-fired form of radiant differs as might be expected very considerably from the electric type of unit.

The first gas-fired radiant tunnel to be used to any extent in this country was developed at the Gas Light & Coke Company's Research Dept., in London, and was described in some detail by Andrew (4) and Chamberlain (2) (Fig. 2).

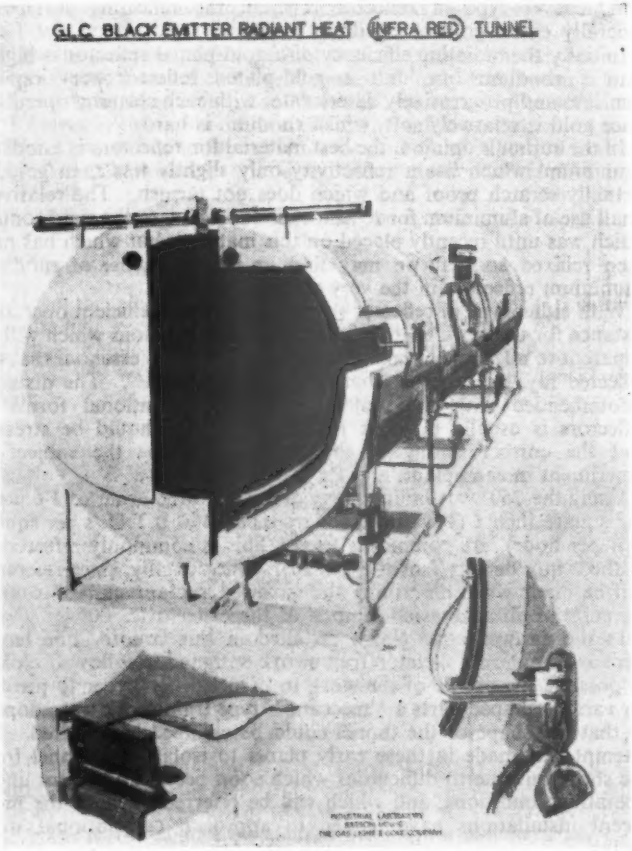


Fig. 2

The unit comprised an inner circular radiating steel sheet and an outer casing acting as a hot gas space, a bar burner using luminous type industrial jets being arranged at the bottom of the space and

for the full length of the tunnel, a burner being fitted for each half section of the tunnel.

For approximately 25% of the radiating surface and at the bottom of this surface was arranged a baffle sheet designed to prevent overheating, and in order to equalize as much as possible the temperature over the whole radiating surface by increasing the heat interchange, ribs at approximately $1\frac{1}{2}$" pitch were arranged over the final section of the radiating sheet.

Adjustable baffle plates were arranged at the point of exit of the flue gases from the annular space so that the velocity of these gases could be adjusted and so obtain maximum heat efficiency.

In the first tunnel, which had an effective internal diameter of approximately 2' 6" and a length of 3', the temperature measured at 12 points over one half of the tunnel varied from a low reading of 625° F. to a high reading of 685° F., the average temperature being 650° F (3).

In order to reduce end losses to a minimum, sliding doors were arranged at the end of the section, though in the case of long tunnels, the doors may be dispensed with, this being essential where a conveyor system is used in conjunction with the tunnel.

It was found that with this first type unit a flux density of 6 watts per square inch per side equivalent to a total flux of 2,900 B.T.U. per square foot per hour were obtained (3).

Subsequent developments of the gas-fired design have indicated that it is possible to obtain fluxes of 50,000 B.T.U. per square foot per hour.

An interesting development of the G.L.C. design was made by Mr. Atkin of the Birmingham Gas Research Dept., and I can do no better than to quote from a paper read by him to the Midland Junior Gas Association in Birmingham (4).

"The particular points considered in the design are as follows:

(1) The side and top are corrugated, as it was thought that not only would an increased radiating effect be obtained but also the radiation would be more unidirectional, thereby speeding up the drying of surfaces which travel through the oven at right angles—such surfaces as occur on box-like articles. (It should be stated, however, that in many cases the conductivity of the metal is sufficient to take care of this point.)

(2) The flue products are reversed at the top panel:
   (a) to avoid the high aeromotive effect of the column of hot gases.
   (b) to increase the scrubbing effect of the flue products.
   (c) to divert the flue products from the conveyor chain.

(3) The cross section is hexagonal; this being more suitable to the drying of rectangular objects having a long length as compared with width.

(4) Bar burners with single injectors are used, enabling luminous or non-luminous flames to be obtained at will.

(5) The burners are accessible for cleaning and lighting up, mica windows being provided.

(6) The two halves are self-supporting and adjustable.

(7) The radiating surface can be replaced easily.'' (Fig. 3.)

Comparative tests were made between the corrugated design and the design using a flat radiating sheet, the radiating temperature in both cases being 650° F.

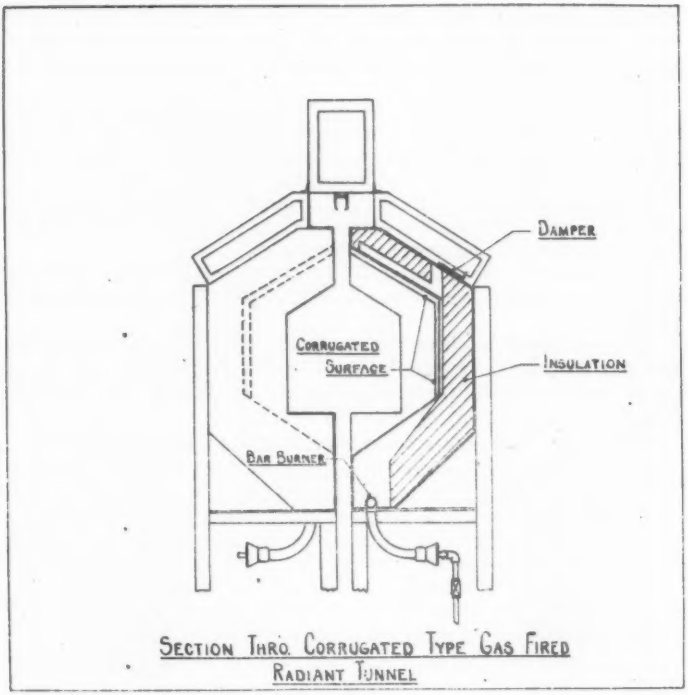


Fig. 3

It was found that a 22 g. sheet matt black painted test panel was heated to 338° F. in one minute, or to 292° F with the flat radiating sheet.

From further tests made it was determined that savings in time up to 20 per cent. with reductions in gas consumption of up to 14 per cent. could be obtained with the corrugated type tunnel.

Other designs of gas-fired tunnels have and no doubt will be developed, and mention should be made that a patent has been obtained by I.C.I. Paints Division for the use of refractory surfaces heated with gas or electricity for temperatures of 1,000° C.

Types of Drying Units.

It perhaps would be opportune at this point to consider briefly other types of drying units of what may be termed conventional types.

Broadly these may be divided into two classes, those employing natural convection and those employing forced convection.

In the first class we have what are widely known as (a) double-cased stoves, and (b) triple-cased stoves.

Before describing these apparatus, perhaps it would be well to establish what is meant by convection heating.

Natural convection can be described as the tendency for hot gases to rise due to the fact that as the temperature of the air or gas increases, then its density decreases and in consequence is displaced by colder air or gas. If a surface is heated above the temperature of the surrounding atmosphere an air movement will occur over the heated surface—the higher the temperature, the faster the air movement.

Double Cased Stoves.

This type of stove consists of an insulated casing forming the working chamber. The heating is carried out by burners, steam coils, or electric elements, generally situated at the bottom of the stove, the venting of fumes and volatiles being accomplished by means of a ventilating stack in the roof of the chamber. An air space is provided at floor level to admit air for combustion and venting (Fig. 4).

Triple Cased Stoves.

The triple cased stove was originally designed for applications where it was assumed, but not always verified, that the products of combustion would cause deterioration of the work to be processed. Essentially the construction comprises an insulated casing built on similar lines to the standard double cased unit, and generally the burner gear is placed at the bottom of the casing. Inside the insulated casing is arranged a further mild steel casing, the floor of which is suitably stiffened to carry the load, and gas spaces are arranged

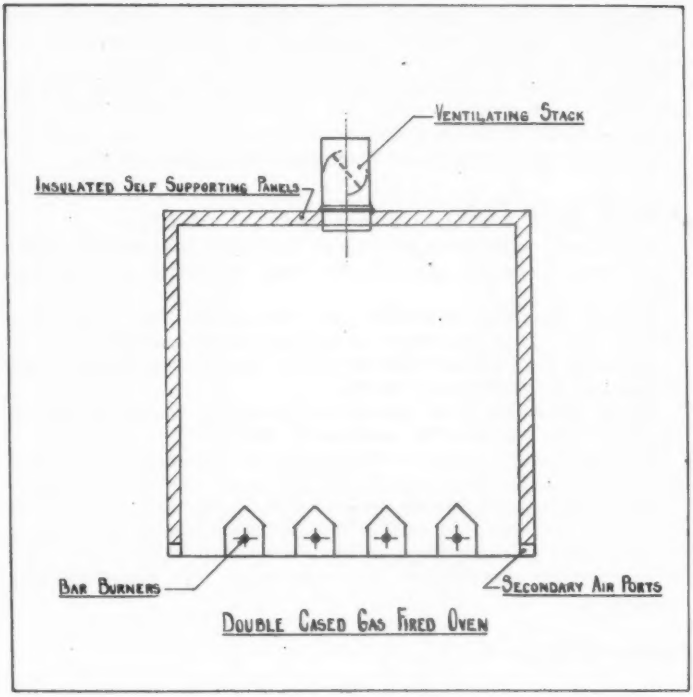


Fig. 4

round both sides and at the top between the insulated casing and the inner mild steel casing. Ventilating stacks are taken generally through the roof of the casing, one connecting to the gas space and one to the working space.

Provision is made in the case of the combustion chamber formed underneath the floor of the working space to admit the necessary air for combustion and similar fresh air openings are provided into the working space in order to obtain a degree of natural convection (Fig. 5).

It will be realized that, with this form of stove, a proportion of the drying process is achieved by natural convection. In the main the heating is by radiation, and a major trouble which has occurred in this type of stove is that the temperature must vary from the side to the centre of the stove, and also from the top to the bottom. A

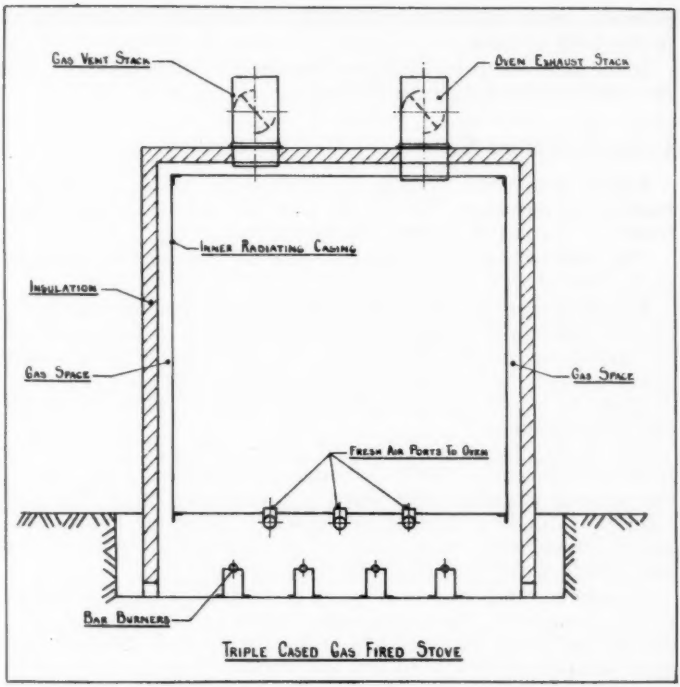


Fig. 5

further difficulty which has been experienced with triple cased stoves is that designers have made insufficient allowance for venting where heavy fuming coatings have to be dried and, in consequence, "blooming" and "washing" of the painted articles has been the result.

In running cost it will be appreciated that the triple cased stove is a comparatively inefficient unit, since in the first place, the inner casing acts as an interchanger, and consequently the amount of air which has to be taken into the inner compartment for venting has, of course, to be heated to the oven temperature and is immediately discharged to atmosphere after once passing through the working space.

In processes where close control of temperature is required,

generally speaking, it is extremely difficult to obtain these conditions in this form of stove.

In the main the disadvantages pertaining to the triple-cased stove also apply to the double-cased units.

Forced Convection Systems.

Forced convection systems are systems in which, in place of natural air movement to transfer heat to the work, mechanical means, i.e., a fan or blower, are employed.

This form of heating should be divided into two classes, described as (1) Forced Convection and (2) Air Circulated Systems.

The disadvantages which have already been pointed out in the case of double-and triple-cased stoves were early apparent, and in an endeavour to equalise as far as possible the temperature difference over the working chamber, propeller fans were employed, designed to break down stratification, which to some extent did improve conditions.

The modern forced air circulated system, however, goes farther. It will be appreciated that if the combustion chamber forms part of the working chamber, then there is a very great possibility that "hot spots" in the working space will occur, mainly due to radiation, and in consequence in this type of stove, generally speaking, the heat source is removed from the working space.

In order to bring heat to the work to be dried, a fan is employed which is coupled to the combustion chamber or heater battery, and delivers heated air into a system of ducting which is disposed with multi-damper adjustment so that the amount of air over the whole area can be correctly proportioned. The exits from the duct system are designed so that the air stream shall entrain the oven atmosphere, and create a condition of turbulence inside the working chamber. This turbulence ensures that the whole of the working chamber is at the same temperature within very close limits.

A further duct system is arranged inside the oven which couples back to the heater and the air is continuously recirculated in order to reduce the amount of heat required to maintain working temperature. A ventilating stack is also provided, with a damper control to evacuate from the system heavy fume, etc.

Having now established in our minds the alternatives available to us, let us next consider the advantages and disadvantages of each.

From a recent publication sent out by one of the lamp manufacturers, it is stated that :

(1) Infra red rays have to some degree the property of penetrating the materials they heat.

(2) Intervening air is not heated.

(3) Since, so it is claimed, there is no great temperature variation throughout the mass of paint, the temperature can be raised very rapidly without risk of blistering.

Thus the following advantages are claimed :

(a) There are no standby losses, since heat is available immediately the lamps are switched on. (This cannot apply, of course, in the case of a gas-fired tunnel.)
(b) There is considerable saving in space.
(c) Efficiency is high.
(d) Fuel is saved.
(e) Time is saved.

Taking first things first, we are told that "infra red" rays penetrate to some extent the materials they heat, the inference being therefore that this penetration does not cause a temperature rise. If we consider a paint film this, particularly in the case of a sprayed one, will be of the order of a few thousandths of an inch thick, and in the case of certain absorbent materials, i.e., materials with high emissivities, it will not be possible to measure the temperature rise in the paint film as distinct from the temperature rise in the base.

The second statement tends to give the impression that there is something mystical about infra red rays. It is very well known that air is transparent to radiant energy, and therefore it is physically impossible to heat air by radiant methods. As to whether this fact is an advantage is highly debatable.

It has been pointed out by Nelson and Silman (5) that for a given area, if the temperature difference from the surroundings is doubled, then the heat energy lost by convection is doubled. It would follow, therefore, that for maximum efficiency the temperature of the air surrounding the object irradiated should be at the temperature to which it is desired the object should attain. This is, in actual fact, being arrived at in the later type of radiant tunnel, which from a constructional viewpoint is rapidly following conventional oven practice (Fig. 5A).

In the earlier plants which comprised open frameworks, it was found necessary to sheet in the sides in order to prevent heat loss due to convection currents and draughts. It was also found necessary to provide hoods over the lamp sections in order to evacuate the fume given off by the painted articles during stoving. It would follow from the above, therefore, that this is no particular advantage in claim 2, rather the reverse.

Under heading (3), let us consider what happens to a newly painted window frame which is subject to solar radiation. If the day happens to be a fine one, then paint blisters will form, even though the intensity of radiation over the whole frame is to all intents and

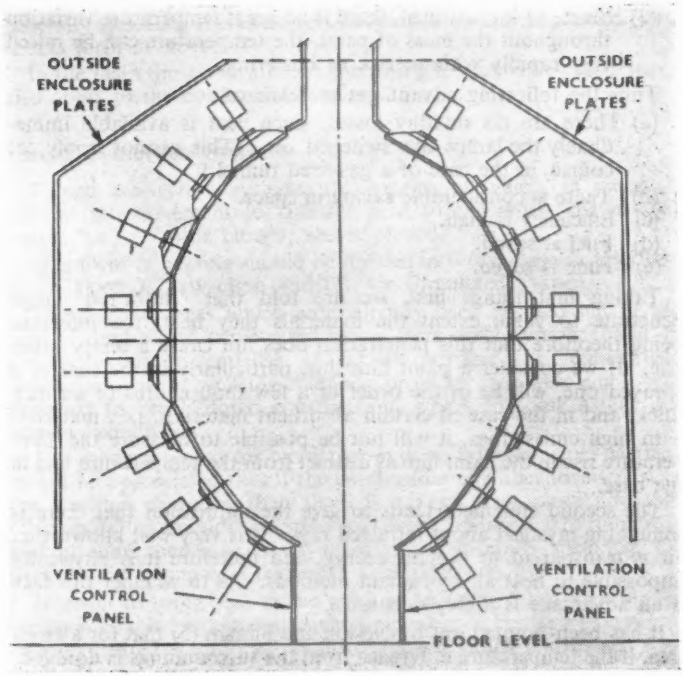


Fig. 5a

purposes equal. The blisters are formed due to the paint film case-hardening, i.e., surface drying, trapping the solvents, which expand due to their rise in temperature, forming a bubble.

In the case of painted articles to be stoved either by radiant or other means, it is of great importance that the rate of heating be controlled in order that blistering or pin-holing does not occur. It is just as easy—in fact, easier—to blister painted articles by radiant methods than by the more conventional natural and forced convection systems.

Before considering the advantages claimed under (a) to (e) above, under (a) it is perfectly true that in the case of the electric tunnel this is ready for immediate use when the lamps are switched on, and in consequence there is no heating-up period. In the case of the gas-fired type, the standby period is usually very short—a matter of 10–15 minutes only.

In the case of the double and triple-cased stove, the heating-up time is generally an extended one, being an hour or more from lighting up until the stove is ready for loading, the time for heating up being progressively longer the higher the operating temperature.

With a well-designed air-circulated stove, and assuming an operating temperature of 250°-300° F., the stove should easily be capable of reaching this temperature within 10–20 minutes.

The claim under (b) is that there is a considerable saving in floor space in favour of the radiant unit. This may be true in the exceptional case, but in the author's experience there is generally little to choose between an air-circulated stove and a radiant unit. If anything the former type unit invariably shows an advantage.

Comparison of Radiant Heating and Forced Convection Systems.

Recently the author was asked to compare the advantages of radiant heating and forced convection systems for a small mass-produced article made in 20-gauge material and approximately $4'' \times 2'' \times 1''$.

In the case of a forced convection system, it was determined that the time of travel through the oven section should be 10 minutes, and that the conveyor could be loaded nine parts wide, with the loading fingers at 4″ pitch along the conveyor length. On this basis the effective oven length was determined as 6′ 0″. In order to compensate for end losses, it was proposed to make the oven 8′ 0″ long, the design proposed being an open-ended through-type one.

In the case of a gas-fired radiant tunnel, the drying time was determined as $2\frac{1}{2}$ minutes, and it was also determined that the parts could be loaded two abreast on the conveyor without risk of shadowing. As in the case of the air-circulated oven, the pitch of fingers along the oven was proposed as 4″. The effective length of tunnel was determined as 6′ 0″, with an overall length of 8′ 0″ in order to compensate for end losses.

In both the above cases, the overall width of the plant was approximately 3′ 0″.

A further interesting example is given by Atkin (7), this time in favour of radiant heating. The following are the details as published : (6).

Time of irradiation	5 minutes 10 seconds
Total time in stove	8 minutes 37 seconds
Output per hour	1,000 articles
Gas consumption	600 c.f. per hour
Heated length	9′ 0″
Length of stove	15′ 0″
Width of stove	3′ 8″
Panel temperature	450–500° F.

It is stated that to obtain a similar output in a convection oven (type not stated) required an effective heating length of 9′ 0″, with an overall length of 25′ 0″ and a width of 4′ 6″, the estimated gas consumption being 400–500 c.f. an hour.

One further example, this time in favour of the air-circulated type oven, may be stated.

It is well known that in the manufacture of decorated metal boxes, the initial stage of manufacture is the printing of the design on the flat sheet. The usual size of plate used is 28″ × 20″, though other sizes are used, depending on the size of the final product. A number of designs are printed on the one sheet, the impression being printed either in a rotary or flat-bed type tin-printing machine. After printing and before stamping, the sheet has to be dried and feeds of 3,000 plates or more per hour are commonly obtained under production conditions.

At first sight it would appear that this is an ideal application for radiant heating, but in practice a forced-air circulated system shows a considerable saving in floor space.

Conveyor Systems.

Conveyor systems have been devised which enable 12 sheets to be carried in each 1′ 0″ of conveyor, the conveyor width being, say, 3′ 0″. This represents a surface area of 20′ 0″ of stock per foot of conveyor, and thus for equivalent length a radiant plant would require to dry the plate in 1/20th of the time taken by the convection stove, which is normally 8-10 minutes from time of entry to exit from the stove, which represents approximately 30 seconds for a radiant unit.

For this particular type of work the author is familiar with stoves in satisfactory operation with conveyors loaded at $\frac{3}{4}$″ pitch, i.e., 16 sheets per foot, which gives an even more favourable advantage in this specialized application to the use of air-circulated stoves.

From the point of view of efficiency, it is very difficult to obtain any reliable figures, and comparison must of necessity be by generalization.

If we consider either gas or electric units, we can first state that both are heat interchangers, since in both cases the heat is transmitted to the work indirectly. No known interchanger has yet been developed with an efficiency even approaching 100 per cent. With the lamp-type unit, we have firstly a high efficiency source which in the case of the gas-filled bulb delivers 67 per cent., and in the case of the vacuum bulb 86 per cent. of the energy input as infra red radiation, and in the former case 8 per cent. and the latter case 6 per cent. as luminous radiation, the balance of the energy input being dispersed as convection and conduction along loads and supports (7). This energy then suffers a further reduction due to the inefficiency

of the reflector, which may have an initial efficiency of 90 per cent. or more, with a mean efficiency, with well-cleaned reflectors, of possibly 85 per cent. This represents the energy available for useful work in the best case of approximately 73 per cent.

Further very considerable losses will occur at the work, since a comparatively small proportion of the available energy will actually be usefully absorbed by the work, the balance being dissipated in the plant. It has been stated that the overall efficiency is as low as 15 per cent., though there are, as far as the author is aware, no published figures.

In the case of the gas-fired tunnel, this employs a radiating sheet as the energy transmitter, and in order to provide high energy densities this sheet is heated to a temperature greatly in excess of the ultimate temperature required on the work. In order to maintain an equal temperature over the radiating surface, it is necessary that the flue gas temperature shall be in excess of the radiating surface temperature, which represents an unavoidable loss in overall efficiency. Further losses must occur between the radiating surface and the work, as in the case of the electric-type unit. A fair overall efficiency figure can be assumed to be 30–35 per cent.

In the case of a modern air circulated unit, either gas or electrically heated, the whole of the heat release from the heat source is taken into circulation and is available for useful work. Of necessity, however, a proportion of this available energy is used to make good radiation losses, and also part of the heat available must be stacked to atmosphere, in order to rid the system of solvent or moisture build-up. Also, in the case of a direct gas-fired plant, air for combustion is admitted to the system, which of course has to be raised to the required working temperature. It can, however, be stated that the air-circulated type of unit, assuming, of course, intelligent operation and setting, has a very much higher overall thermal efficiency than either a gas or electric radiant unit.

Fuel Consumption.

It must follow that if the efficiency of a system is low, then there can be no saving in fuel consumption—rather the reverse, and here it may be permitted to quote published figures.

In an example already given earlier in this paper, when describing a small radiant installation, it may have been noted that the gas consumption with an output of 1,000 parts per hour was 600 c.f. of town gas per hour, and later it was stated that in the case of a convection stove the estimated gas consumption was 400-500 c.f. per hour, or a saving of between 33 and 20 per cent.

It is well known that the early publicity given to the use of

radiant drying plant instanced the stoving of the "Jerrican." Atkin ([8]) gives the following comparison.

Details of Gas-Fired Conveyor Convection Oven.

Stoving length	32′ 6″
Oven body	38′ 0″
Overall length	59′ 6″
Width inside	12′ 0″

Details of Electric Infra Red Plant.

No. of Lamps—preliminary dryer—4 banks of 36	144	36 K.Wh.
No. of Lamps—main dryer—32 banks of 36 ...	792	198 K.Wh.
Total	936	234 K.Wh.

Comparison of Costs and Output.

	Gas Convection Oven	*Electric Infra Red*
No. of cans stoved per hour	360	360
Stoving time	10	Preliminary 1 minute
		Main ... 5½ minutes
		Total ... 6½ minutes
Energy used ...	1,340 c.f. hour	234 K.Wh.
Cost of energy ...	3s. per 1,000 c.f.	.65d. per K.Wh.
Cost per hour ...	4s.	12s. 9d.

A further instance with which the author was associated was an installation required for stoving landing strips, which had an overall size of 11′ 6″ × 6′ 6″ × 2″ thick. Three alternatives were proposed for stoving, gas and electric radiant units, and an air-circulated gas-fired oven.

In the case of the gas-fired radiant tunnel, the estimated gas consumption for an output of 20 strips per hour was given as 3,000 c.f. hour approximately, costing, with gas at 3s. per 1,000 c.f., 9s. per hour. The electric radiant tunnel was rated at 96 kWh, which, with current at .65d. equals 5s. 2¼d. per hour. The gas-fired air-circulated oven was estimated to run at 500 c.f. hour—1s. 6d. per hour with gas at 3s. per 1,000 c.f.

There is, however, in favour of the electric-type unit the fact that the plant is ready for immediate use on switching on the lamps, whereas with other types of dryer there is a heating-up period, though, as has previously been pointed out, in well-designed modern plant this should not exceed 30 minutes.

Time-Saving Qualities.

Finally, we are told that time is saved by the use of radiant type plants. There is really no argument against this fact, since with

high energy densities the temperature lead is very great, and in consequence quick heating-up rates can be obtained. It may be of interest, however, to compare electric radiant, natural convection, and forced-air circulated oven heating-up rates for identical test panels.

The test panel in each case was 6″ square and temperature rise was measured by a thermo couple bolted to the centre of the plate. The same panels were used in each case.

TABLE I

20 g. Sheet

	Natural Convection	Electric Infra-Red	Forced Convection
30 seconds ...	130° F.	138° F.	150° F.
60 ,, ...	163° F.	205° F.	235° F.
90 ,, ...	192° F.	275° F.	270° F.
120 ,, ...	215° F.	340° F.	282° F.
180 ,, ...	247° F.	—	288° F.
240 ,, ...	264° F.	—	293° F.
15 minutes ...	290° F.	—	—

TABLE II

10 g. Sheet

30 seconds ...	100° F.	120° F.	107° F.
60 ,, ...	115° F.	145° F.	150° F.
90 ,, ...	130° F.	165° F.	190° F.
120 ,, ...	143° F.	180° F.	212° F.
180 ,, ...	165° F.	204° F.	237° F.
240 ,, ...	183° F.	218° F.	255° F.
5 minutes ...	200° F.	230° F.	267° F.
10 ,, ...	252° F.	264° F.	288° F.
15 ,, ...	271° F.	283° F.	290° F.
20 ,, ...	279° F.	289° F.	290° F.

TABLE III

3″ Thick Casting

30 seconds ...	86° F.	80° F.	100° F.
60 ,, ...	92° F.	85° F.	117° F.
90 ,, ...	97° F.	90° F.	130° F.
120 ,, ...	102° F.	95° F.	138° F.
180 ,, ...	110° F.	100° F.	151° F.
240 ,, ...	118° F.	105° F.	164° F.
5 minutes ...	125° F.	110° F.	175° F.
10 ,, ...	160° F.	132° F.	214° F.
15 ,, ...	177° F.	153° F.	240° F.
20 ,, ...	195° F.	170° F.	258° F.

In the above tests, the natural convection stove showed a temperature on the indicators of 297/310° F. ; the forced convection stove was controlling between 298–302° F. The laboratory type infra red unit was operated with the lamps at 4″ centres for two minutes, and at 8″ centres for 18 minutes.

In order to determine the effect of radiation from the oven walls in the case of the forced-air circulated unit, a further series of tests were carried out with the test panel shielded from wall radiation. The results are tabulated hereunder :

TABLE IV
20 g. Sheet

Time		Temperature
30 seconds	...	110° F.
60 ,,	...	160° F.
90 ,,	...	220° F.
120 ,,	...	255° F.
150 ,,	...	270° F.
180 ,,	...	283° F.
210 ,,	...	287° F.
240 ,,	...	290° F.
270 ,,	...	293° F.
5 minutes	...	294° F.

TABLE V
10 g. Sheet

30 seconds	...	107° F.
60 ,,	...	155° F.
90 ,,	...	205° F.
120 ,,	...	235° F.
150 ,,	...	247° F.
180 ,,	...	258° F.
210 ,,	...	267° F.
240 ,,	...	272° F.
270 ,,	...	277° F.
5 minutes	...	281° F.
7½ ,,	...	290° F.

From the results given above, it would appear that in the case of the 20 g. sheet, there is little to choose between the electric radiant and forced convection stove for the first 90 seconds, when the advantage was certainly with the radiant unit. It must be remembered that at this point, the temperature head in the case of the forced-air circulated unit was then only 8-12° F.

In the case of the 10 gauge plate, the advantage was certainly in favour of the forced convection oven, and even more so in the case of the thick casting.

Conclusion.

The time is now ripe to draw conclusions. It would appear from what has already been said that the author has a poor opinion of the use of radiant heating for drying applications. This deduction would be erroneous. It must be said that the publicity and claims so far made for its use have given an impression of universal applicability, which in point of fact is very far from the truth.

Where parts of plain section and of light gauge and identical shape require to be stoved, there is certainly a case, particularly when the covering to be dried is a sprayed one, but for parts of intricate shape, of varying or heavy section, then the advantage is definitely in favour of a well-designed air-circulated drying system. Generally speaking, also, a forced convection stove will give better results in the case of dipped work than a radiant type unit.

Two instances which come to mind for the use of radiant plant are the drying of lacquer on continuous steel strip, which has never been satisfactorily accomplished by means of an air-circulated or natural convection system, and skin drying of moulding boxes where complete drying is not called for.

An interesting development of electric radiant units has been made by Messrs. Joseph Lucas, Birmingham. They have adopted a system of painting all machines in bright contrasting colours which, it has been found, adds to production efficiency. It was discovered, however, that an air-drying paint rapidly deteriorated, especially at points where oil was present. It was discovered, however, that a stoved coating was to a degree unaffected by oil. In consequence, a portable radiant unit was designed with the lamps adjustable in any direction, and thus they are now able to stove-finish their presses and machine tools "in situ," and to obtain an oil-resistant coating.

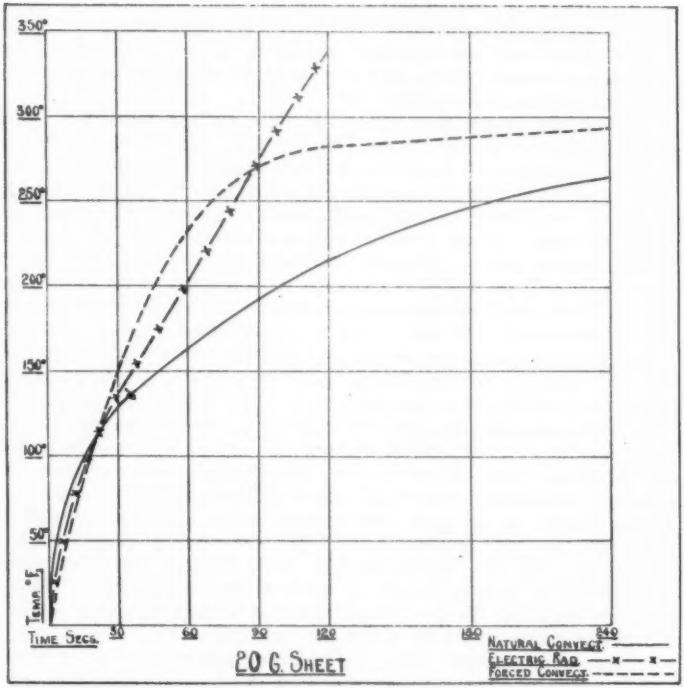
To compare the merits of gas and electric radiant plants, in the author's opinion the advantage must lie with the gas-fired type, which has higher energy densities than in the case of the lamp-type unit, uses a cheaper fuel, generally speaking, than electricity, and is more flexible from the point of view of control. A well-designed air-circulated unit, however, for the majority of applications possesses advantages over either type of radiant unit. It is completely flexible inside its designed temperature range, can be controlled below the spoiling temperature of the work being treated whilst still giving good heating-up rates, is more efficient thermally, and can handle an infinite variety of work without adjustment. Also, generally speaking, the floor space occupied for an equivalent output will be no greater than for a radiant-type unit.

It may well be that when more development work has been carried out on the radiant-type unit, then many of the disadvantages outlined will disappear and a wider use of this system can be made.

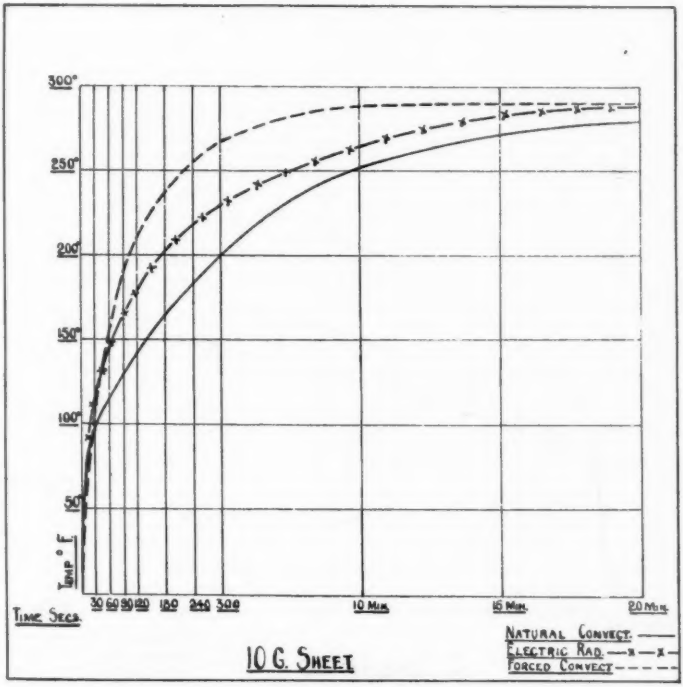
Interesting developments may be expected in the near future in

the use of a composite plant, embodying a radiant section for quick heating with a following forced convection system to complete the process.

Finally, the writer wishes to put on record his indebtedness to Messrs. Peters, junr., and Parkes, of Messrs. Docker Bros., Birmingham, for their assistance in making tests; to Mr. H. Silman of Messrs. J. Lucas, Birmingham, and Mr. F. L. Atkins, of Birmingham Gas Department, for permission to quote from their publications; to Mr. W. Detrichs, of the Gas, Light and Coke Co., for photographs and information in respect of gas-fired radiant units; and to Messrs. B.T.H. Ltd., for photographs of electric units. He also wishes to express his thanks to his colleagues for their encouragement, criticism and assistance.



Graph of Table I.



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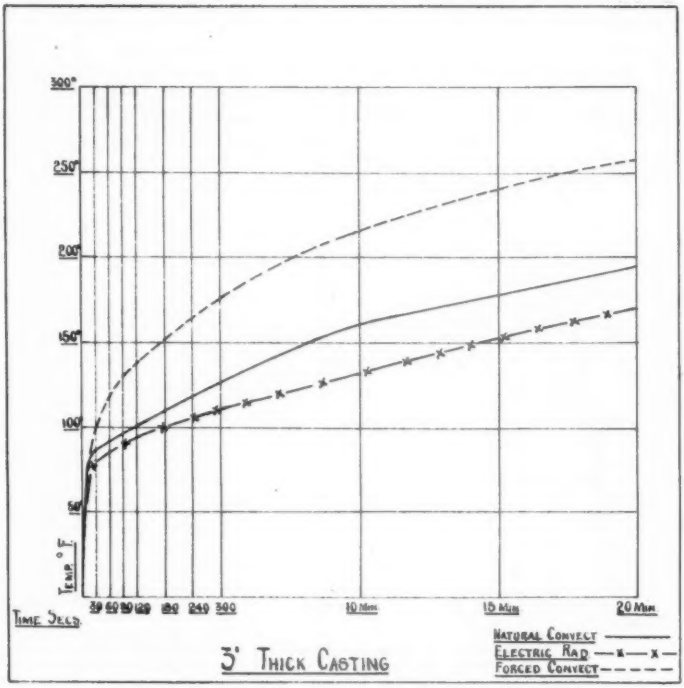

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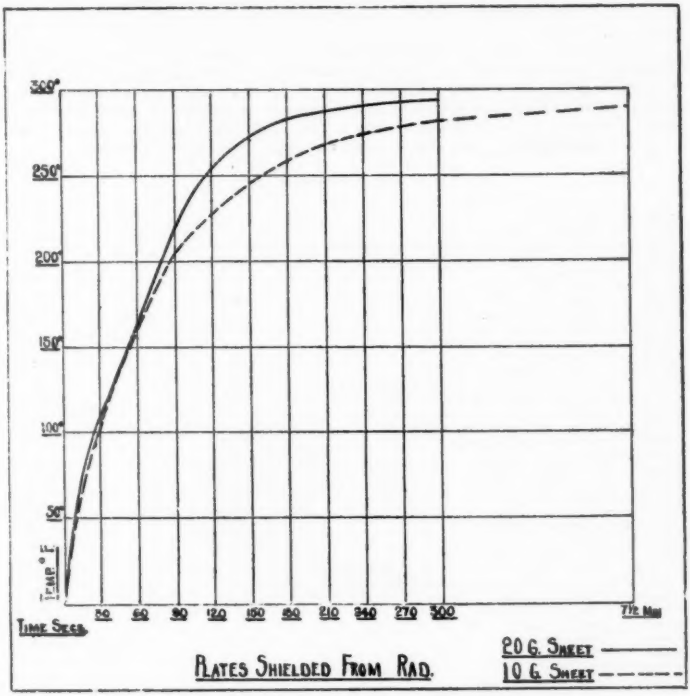

Combined Graph of Tables IV and V.

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INDEX TO ADVERTISEMENTS

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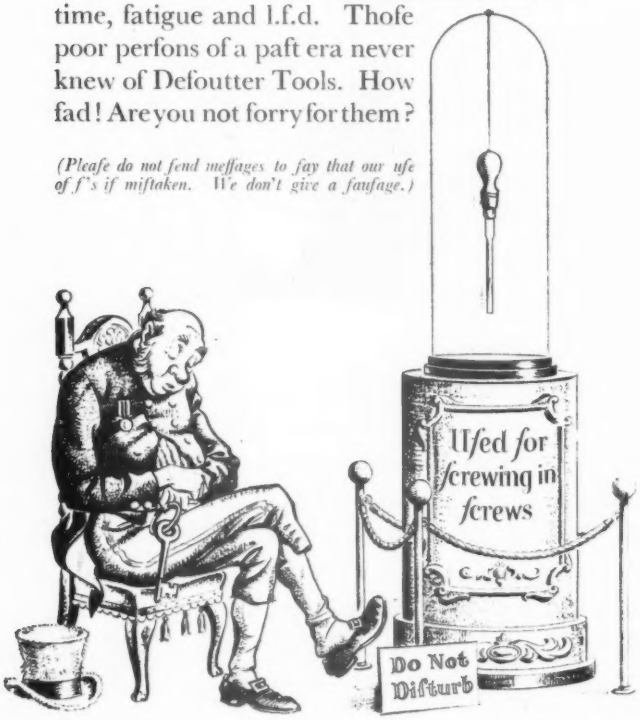

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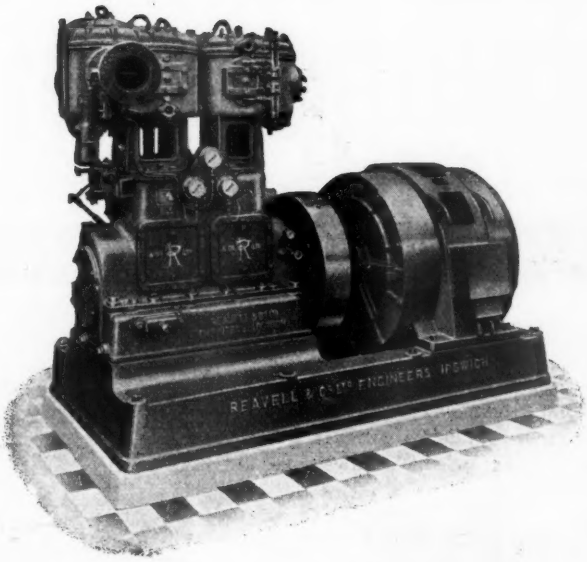

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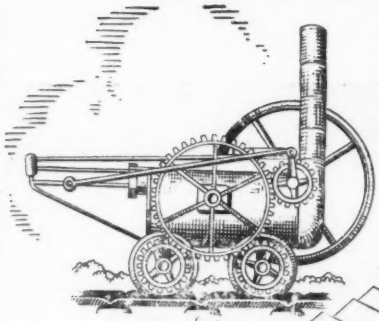

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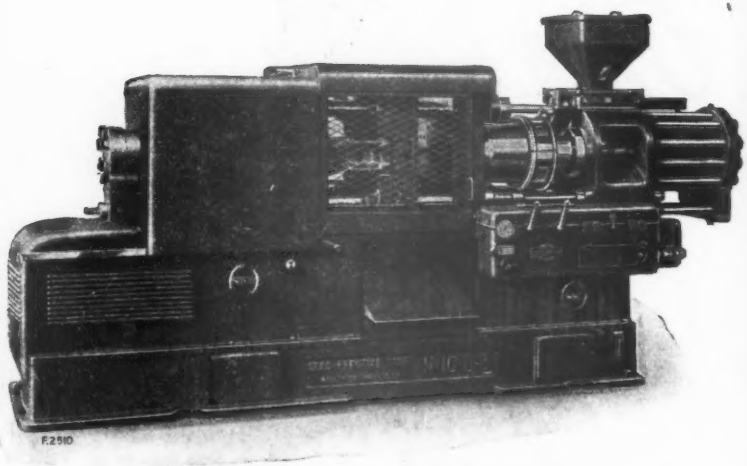

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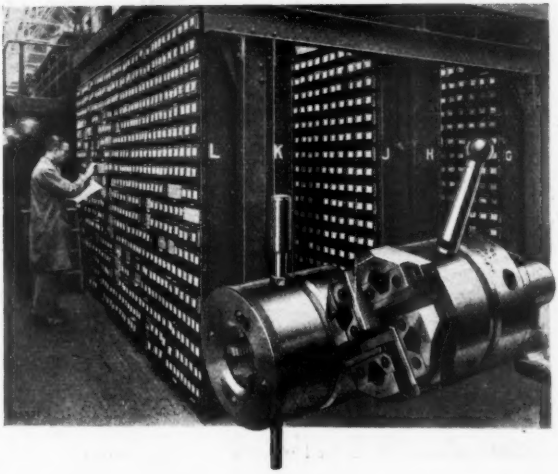

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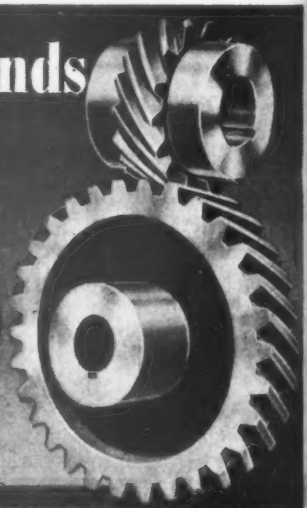

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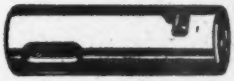

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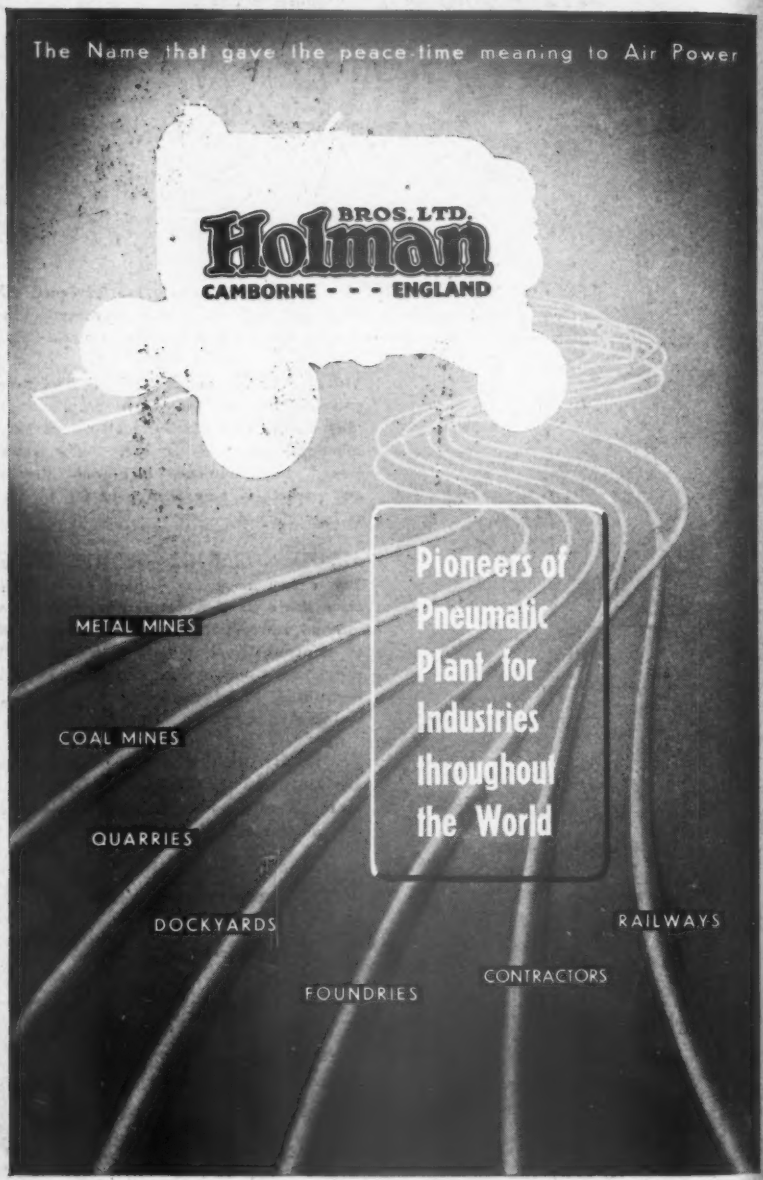

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